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INFORMATION CIRCULAR

CORUNDUM

BY

ROBERT W. METCALF

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UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

CORUNDUM[1]

By Robert W. Metcalf[2]

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COMPOSITION AND PROPERTIES

Corundum, natural alumina, or aluminum oxide (Al_2O_3) is the hardest mineral known except diamond. Theoretical composition is Al 52.9 percent and O 47.1 percent, but it always contains small quantities of impurities, chiefly silica, iron, and lime. The melting point of corundum is above 1950° C., and it is insoluble in the strongest acids. Its hardness (9 on the Mohs scale) varies slightly according to purity, and its specific gravity ranges from 3.95 to 4.10, 4 being a fair average. The index of refraction is 1.760 to 1.768 and its streak is white. Luster is adamantine to vitreous, some specimens pearly, and color varies widely from white, gray, pink, and blue to black, brown, or bronze. Gem varieties are transparent or translucent, and of more brilliant coloring - red, blue, yellow, purple, or green.

Corundum occurs in opaque massive or block structure with parting planes little developed or only roughly delineated and in granular form as minute crystals or small, irregular grains interspersed throughout the contact zones of schists and gneisses.

The crystal structure exhibits prominently prismatic, rhombohedral, and pyramidal forms of the hexagonal system. Long, six-sided prisms may taper from the middle toward each end, or the crystals may be short and stubby. The prisms are commonly rounded into barrel-shaped outlines, have deep horizontal striations on the ends, and may exhibit distinct cross hatching on the faces due to twinning. A well-developed basal parting causes the crystals to break readily at nearly right angles, revealing smooth, flat surfaces.

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[2] Assistant mineral economist, Nonmetal Economics Division, Bureau of Mines.

Outstanding characteristics of the so-called common or abrasive corun are its great hardness, high luster, specific gravity unusually high for a nonmetallic mineral, prominent basal cleavage, and inconspicuous bluish or gray color.

VARIETIES

The abrasive or so-called common corundum is the subject of this study Other varieties, however, will be mentioned briefly. Pure, translucent, or transparent corundum has high value as a gem and, according to its color, is called sapphire (blue), ruby (red), oriental amethyst (purple), aquamari (light blue-green), oriental emerald (deep green), or oriental topaz (yellow). The most important of these gems are the prized sapphires and rubies. An impure granular variety containing magnetite, hematite, or iron spinel is emery, which is also used as an abrasive.

ORIGIN AND OCCURRENCE

Corundum apparently was separated out of molten igneous material or magmas containing an excess of alumina at an early stage in the cooling process. It occurs both as an accessory mineral in metamorphic rocks, such as crystalline limestones, gneiss, or mica schist, and as an original constituent of feldspathic igneous rocks, such as coarse pegmatites and granite particularly those with little or no free silica, the syenites or nephelin syenites. Corundum may be scattered as small crystals throughout certain types dikes and also appears in alluvials such as stream sands, where its hardnes and chemical inertness have prevented disintegration.

Minerals associated with corundum in acid rocks (gneiss or granite) ar garnet, magnetite, pyrite, zircon, and occasionally monazite and sodalite. In peridotites and other basic rocks associated minerals may be olivine, magnesian amphibole, pyroxene, chromite, spinel, and rarely plagioclase. In contact zones the minerals present (aside from corundum) may be biotite, muscovite, garnet, staurolite, tourmaline, rutile, and others. In regionally metamorphosed rocks, corundum may be associated with biotite, muscovi amphibole, sillimanite or kyanite.

Corundum, as above indicated by its mineral associations, has a wide geological distribution and has been found in at least 20 different rock types and in at least 35 countries. Many of these occurrences are commercially unimportant and have mineralogical significance only. The chief countries known to possess deposits of commercial importance are the United States, Canada, Union of South Africa, India, Madagascar, and Russia.

United States

The chief domestic deposits of corundum are in a long, comparatively narrow region, consisting largely of basic igneous rocks, extending from Massachusetts southward, roughly paralleling the Atlantic coast some distance inland and reaching into Alabama. The principal constituents are peridotite, gabbro, and other related basic magnesian rocks. The more important localities where outcrops of corundum have been found throughout this region are Laurel Creek, Rabun County, Ga.; Corundum Hill, Macon County, N. C.; Webster, Jackson County, N. C.; and Clover, York County, S. C. Particularly in North Carolina and Georgia the corundum forms a series of elongated bodies varying in width from a few inches to 15 feet along the contact zone of the peridotite with schists and gneisses and is occasionally found in the peridotite. Outside of this Appalachian belt, corundum has been reported from California, Colorado, Idaho, and Montana, although actual mining has been done only in Montana.

The occurrence of corundum was first reported in the United States in 1819 near Laurens, S. C. The finding of one small, hexagonal crystal, however, did not lead directly to mining operations. Actual mining was not undertaken until 1871, when Col. Charles W. Jenks of Boston obtained the mineral for its abrasive properties at Corundum Hill, Macon County, N. C. Gem corundum found associated with the abrasive material was recovered as a by-product. Organized mining was started at Laurel Creek, Rabun County, Ga., in 1880 and continued actively until 1893. Corundum was recovered from other mines in Georgia and North Carolina up to 1905. Deposits in Gallatin County, Mont., also yielded a few hundred tons of corundum in the 3 or 4 years preceding 1904.

All corundum operations in the United States were suspended about this time, and no further output was reported until the World War I period. In 1917 and 1918, some domestic material was sold in response to a war demand for abrasives. During the interval from about 1906 until 1921, supplies of corundum were obtained largely from Canadian sources. With the stoppage of Canadian production, followed by the closing down of a plant recovering corundum from tailings, American industry turned to the Union of South Africa, particularly the Transvaal, which has remained the chief source of corundum since 1921. However, small tonnages have occasionally been received from Rhodesia, Madagascar, and India. From 1918 until very recently no marketed production of corundum has been reported in the United States.

World War II created a new and pressing demand for corundum. To locate domestic supplies and thus lessen the dangers and uncertainties of a long ocean haul, an intensive search of areas formerly producing corundum, as well as possible new sources of commercial deposits, was undertaken by the Bureau of Mines and the Geological Survey of the United States Department of the Interior and by the War Production Board. Localities in Georgia and North Carolina particularly, and deposits in Montana and other States were reexplored. Meanwhile, production of corundum was started about the middle of 1943 near Clover, York County, S. C. This operation, however, has since been discontinued. Exploitation of deposits in Gallatin County, Mont., said to be of high quality, also has been reported. Production may be expected about October or November (1944), but approximate tonnage cannot be estimated as yet.

The following table shows the production of corundum in the United States, by years. For some of the early years corundum and emery were reported together, and it has not been possible to give separate figures.

Marketed production of corundum in the United States, 1880-1943

Year	Short tons	Value	Year	Short tons	Value
1880 1/	1,044	$29,280	1896	491	$37,739
1881	500	80,000	1897	153	20,523
1882	500	80,000	1898	539	101,110
1883	550	100,000	1899	500	55,000
1884	600	108,000	1900	505	38,515
1885	600	108,000	1901 1/	4,305	146,040
1886	645	116,190	1902 1/	4,251	104,605
1887	636	114,480	1903 1/	2,542	64,102
1888	589	91,620	1904 1/	1,916	56,985
1889 1/	2,245	105,567	1905 1/	2,126	61,464
1890 1/	1,970	89,395	1906 1/	1,160	44,310
1891	521	52,100	1907-16	-----	-----
1892	321	63,000	1917	820	67,461
1893	648	71,772	1918	365	38,100
1894	250	42,924	1919-42	-----	-----
1895	150	27,425	1943	(2/)	(2/)

1/ Includes emery; separate figures unobtainable.
2/ Data confidential.

Canada

Canadian corundum occurs in syenites and nepheline syenites in Haliburton Hastings, Peterborough, Renfrew, Frontenac, and Lanark Counties. They take the form of dikes or intrusive masses in gneisses and are found in three roughly parallel narrow belts in the southeastern part of the Province. The largest and by far the most important of these regions stretches with some barren intervals over a hundred miles through Haliburton, Hastings, and Renfrew Counties and has a maximum width of 6 miles. Virtually all of the reported output has come from the eastern end of this belt, partly from the Burgess mines, Carlow Township, Hastings County, and particularly from the Craig mine on Robillard Mountain, Raglan Township, in the adjacent Renfrew County. The Craig mine was actively exploited from 1900 to 1913, when the mill was destroyed by fire. Later a small mill was built to work over accumulated stocks of tailings. This project, however, was discontinued in 1921. Recently, investigation of these occurrences has been renewed. However, the deposits are said to be comparatively shallow and the remaining commercial ore of limited extent. Although the old ore dumps probably contain small quantities of good material, it is doubtful whether under normal conditions its handling and separation would be feasible.

Another and much smaller corundum-bearing area is in Methuen and Burleig Townships about 25 miles south of the Main or Northern belt described above.

The third belt containing corundum is in Frontenac and Lanark Counties, considerably east and somewhat south of the Methuen deposit. No production has been reported from these areas. The history of production of corundum in Canada is indicated in the following table.

Shipments of Canadian grain corundum and quantities exported (largely to the United States), 1900-21[1]

Year	Total shipments		Exports (short tons)
	Short tons	Value	
1900	3	$ 300	-----
1901	387	46,415	302
1902	768	84,465	662
1903	703	77,510	618
1904	993	109,545	877
1905	1,644	149,153	1,504
1906	2,274	204,973	2,112
1907	1,892	177,922	1,728
1908	1,089	100,398	990
1909	1,491	162,492	1,362
1910	1,870	198,680	1,764
1911	1,472	161,873	1,380
1912	1,960	239,091	1,897
1913	1,177	137,036	1,154
1914	548	72,176	534
1915	262	33,138	240
1916	67	10,307	59
1917	188	32,153	172
1918	137	26,112	137
1919	-----	-----	-----
1920[2]	196	24,547	176
1921[2]	403	55,965	403

[1] No production or shipments since 1921.

[2] Grain corundum recovered from tailings.

Union of South Africa

Corundum generally occurs in South Africa in one of three forms: (1) Loose or isolated crystals derived from pegmatitic intrusions in decomposed or partly decomposed country rocks, almost universally basic in character; (2) boulder corundum, large lumps in outcrops of corundum-bearing rock that has resisted disintegration and loose pieces scattered over the surface or within partly decomposed rock; and (3) lode, vein, or reef corundum, lenticular masses of rock locally called "plumasite," composed largely of corundum and a white acid-type plagioclase feldspar. Most of the corundum produced has been of the first type.

The principal deposits in the Union are in northern and northeastern Transvaal, in the Zoutpansberg and Pietersburg districts and to the east in the so-called "Low Country." Corundum also is found in other sections of Transvaal and in other parts of the Union, notably in Orange Free State, in the Piet Retief district of Swaziland, near Krantzkop in Natal, and near Steinkopf in Little Namaqualand.

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Production in the Union of South Africa began in 1912 in the Transvaal. Sales or shipments for the next year or two were entirely from Namaqualand. Thereafter virtually all shipments, aside from a small quantity from Natal and small quantities from Namaqualand, have originated in the Transvaal. Sales remained small until World War I years, particularly 1917 and 1918, when, under the influence of the war demand, output greatly increased. Shipments since that time have been maintained actively, and the Union of South Africa has continued to be the leading supplier of this important abrasive.

Although individual corundum crystals may weigh up to 300 pounds, most of them range from about 1/8 inch to 4 inches in length. However, sizes and grades of crystal corundum, which are controlled under Government grading regulations, are based on total alumina content and certain designated screen limits, as follows: A, Not less than 92 percent Al_2O_3; B, 90 percent up to 92 percent Al_2O_3; C, 85 percent up to 90 percent Al_2O_3; and D, less than 85 percent Al_2O_3. Sizes are classified according to the following scheme: Coarse (1), one-half inch diameter and over; medium (2), one-fourth to one-half inch in diameter; fine (3) one-eighth to one-fourth inch in diameter; and mixed (M), one-eighth inch in diameter and over. All the above sizes are determined on a round-hole screen. Sixteen grades are recognized under this system and are designated by symbols such as A1, B2, C3, etc.

Because of consumer requirements the chief export trade is in the three grades - A1, with a minimum Al_2O_3 content of 92 percent and diameter of one-half inch or over; A2, with a minimum of 92 percent Al_2O_3 and diameter of one-fourth to one-half inch; and B3, with a minimum of 90 percent Al_2O_3 and diameter one-eighth to one-fourth inch. Small quantities of C-grade material may occasionally be exported, but this generally is "degraded" material or portions of shipments found not to come up to specifications.

Boulder corundum also is exported, in somewhat larger quantities in recent years, although perhaps only about 25 to 35 percent of the total shipments. Boulder, which may contain 50 to 80 percent corundum, requires no preparation other than crushing or breaking into pieces or chunks small enough to be readily handled, or up to about 1 cubic foot in volume.

The market for South African corundum has been maintained for many years in the United States, in spite of severe competition from other "hard" natural abrasives and from the manufactured products - silicon carbide and especially aluminum oxide. Although corundum seems peculiarly adapted to certain specialized applications, one of the chief factors responsible for the continued demand for corundum in this country is the fact that the crushing, grading, and distribution of imported material have been handled almost entirely by one firm. The contrary is true of Great Britain, where original difficulties with a product often of rather uncertain quality led to dissatisfied customers and encouraged the greater use of emery and artificial abrasives. Much of the trouble formerly experienced has now been obviated by rigid Government-controlled standards for export shipments. The early unfavorable publicity however has persisted and still retards the more general employment of corundum in England.

The history of production in the Union of South Africa is shown in the following table. The figures given are exports, but domestic consumption is so small that they represent production quite closely.

Sales (exports) of corundum in the Union of South Africa, 1912-40 1/, in short tons

Year	Short tons	Value	Year	Short tons	Value
1912	111	£ 659	1927	1,064	£ 8,473
1913	13	128	1928	2,019	12,696
1914	12	144	1929	3,607	19,879
1915	68	480	1930	2,548	17,635
1916	755	7,762	1931	1,129	10,357
1917	2,629	13,038	1932	362	2,621
1918	3,876	26,260	1933	1,304	9,531
1919	179	1,486	1934	3,202	23,844
1920	261	1,446	1935	4,775	36,552
1921	123	770	1936	4,853	38,240
1922	2,024	15,492	1937	2,466	18,817
1923	2,815	22,543	1938	1,540	12,454
1924	1,868	13,284	1939	2,625	18,355
1925	1,832	13,229	1940	4,211	36,610
1926	5,996	44,871			

1/ Data since 1940 are confidential.

India

Deposits of corundum are widely distributed throughout India. Although total reserves are said to be large, for the most part actual mining of abrasive corundum has been limited and often is done by local herdsmen or farmers. No systematic mining operations exist in most areas. However, considerable trade has been carried on for many years, particularly in the bazaar cities, such as Agra, Delhi, and Jaipur. The corundum sold by producers to agents of dealers in the larger cities is utilized by armorers and lapidaries.

Deposits have been worked more or less regularly in the Coimbatore and Salem districts of the Presidency of Madras, at Golhushully and Kulkairi in Mysore, in Kashmir, in the Khasi Hills in Assam, in Rewah Province, and in Hyderabad. Other provinces and native states said to contain more or less extensive deposits are Bengal, Burma, Central Provinces, Punjab, and Travancore. Corundum usually occurs as crystals disseminated throughout gangue rock, such as weathered syenites and schists containing pegmatite inclusions, diorites, peridotites, and others.

Russia

Corundum is known to occur at a number of places in the western part of the Ilmen Mountains near Kyshtym, Molotov region (Perm), R.S.F.S.R., and other small towns in this region. A more recent discovery of good-grade corundum has been located in Asiatic Russia near Lake Tscherkakul, in the Bajan-Aul division of the Pavlodar district Kazakh S.S.R. Fairly large tonnages from this deposit are said to have been mined and shipped for industrial use. No production or shipment data, however, are available.

Madagascar

Production of corundum in Madagascar has fluctuated widely since 1910, ranging from over 1,000 tons in 1913 to virtually none in 1931. Output was resumed in 1936. The material occurs in soft, decomposed siliceous rock, forming so-called "red earth," which blankets a large part of the island, to a depth of 60 feet in some places. The minerals are found in place in the soft, altered mass on the tops and sides of hills or where rains have washed away the topsoil. The corundum and other heavier minerals are concentrated at the botton or on the sides of the hills. Deposits occur at many places, particularly in the southeastern and eastern parts of the island, near Ambositra, Nevatana, and Betafo.

Other Countries

Corundum is widely distributed and has been recognized in at least 35 different countries in all continents. Corundum is known in several countries in southern or central Africa other than the Union of South Africa, particularly in Southern Rhodesia, South-West Africa, and Portuguese East Africa, including Portuguese Nyasaland. It also occurs in many widely scattered regions, such as Afghanistan, the Federated Malay States, Australia, Italy, Brazil, China, Thailand, and other Far Eastern areas. Although small outputs have been obtained in various years from certain of these countries, most of these deposits are not of commercial importance.

IMPORTS

The following table shows imports of corundum for consumption in the United States insofar as data are available.

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Imports for consumption of corundum and corundum products, 1924-41 1/

Year	Corundum ore		Emery and corundum grains (ground, pulverized, or refined)		Paper and cloth of emery and corundum		Wheels, files and other manufactures of which emery or corundum is chief material	
	Short Tons	Value	Pounds	Value	Reams	Value	Pounds	Value
1924	3,310	$121,036	2/416,895	2/$17,820	3/110,302	$25,030	70,096	$29,088
1925	1,643	81,273	2/225,426	2/ 10,063	3/269,836	61,315	65,896	33,316
1926	5,411	302,189	305,779	12,946	3/562,419	86,698	57,271	31,899
1927	1,269	70,038	230,694	19,595	13,956	52,147	94,999	51,600
1928	1,568	82,867	339,236	12,413	7,152	41,817	100,962	51,148
1929	3,783	200,739	871,549	49,321	10,273	43,440	292,982	99,830
1930	3,017	160,559	598,788	39,222	5,143	27,278	71,694	38,476
1931	716	37,039	125,933	6,364	6,389	33,910	73,186	40,001
1932	188	8,258	21,348	937	9,394	60,054	77,327	32,226
1933	1,036	49,442	48,257	3,067	7,053	63,181	100,778	48,833
1934	2,187	134,884	91,855	5,935	2,956	26,185	81,131	47,882
1935	5,056	309,194	114,801	7,815	2,507	22,747	108,382	62,506
1936	4,790	290,221	390,111	30,125	2,494	18,215	136,966	78,677
1937	2,085	134,574	329,121	29,445	3,276	31,937	4/123,106	4/72,925
1938	2,098	138,629	65,608	6,155	2,205	67,062	6,503	3,221
1939	1,964	104,724	129,237	9,793	2,479	72,966	10,604	5,043
1940	2,922	165,270	134,606	9,262	1,562	91,112	4,348	2,473
1941	5,865	287,102	102,906	4,021	2,975	165,544	786	476

1/ Before 1924 imports for consumption of corundum ore were not reported separately. For security reasons data since 1941 cannot be published.

2/ Includes corundum grain as follows - 1924: 31,278 pounds $1,915; 1925: 10,980 pounds, $1,018.

3/ Pounds.

4/ Classification changed to read as follows: "Wheels, files, and other manufactures of emery or corundum or garnet."

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USES

Corundum is used chiefly in grinding, dressing, and polishing metals and glass and has been used to a smaller extent in processing and smoothing stone, wood, and other materials. It has been found especially desirable for iron, steel, and optical glass.

Before use as an abrasive, corundum must be crushed and reduced to grains, powders, or flours. This ground product may be used directly as a cutting, roughing, or polishing agent, as coated abrasive paper or cloth, and in the manufacture of abrasive wheels, cylinders, blocks, and files of varying size and shape. Abrasive wheels are of four types, designated according to the kind of binder employed. In the vitrified wheel, the corundum grain mixed with clay and fluxing materials such as feldspar is molded, dried, and fired at high temperatures in special kilns. The silicate or chemical wheel is bound by silicate of soda. Elastic and rubber abrasive wheels are the other two types, the bond for the former being shellac and for the latter, of course, rubber. Both the rubber and the shellac wheels are made in thin crosssection and used as cut-off wheels or to cut and grind narrow slots in metal. In the manufacture of blocks, files, and other shapes the vitrified type is preferred.

The coarse-grade products are made into grinding wheels, especially snagging wheels for malleable iron and steel. These wheels are employed in grinding and processing hard steels, in the grinding and manufacture of shells, in the manufacture of lathe tools and high-speed tools, and in making boring tools and cutters, gear differentials, carburetors, surgical instruments, and similar high-grade products usable in or applicable to industrial and war activity. Snagging wheels are particularly useful at the present time in the production of forgings and castings for tanks and other military equipment. Substitution of manufactured abrasive wheels in this use, it is claimed, would reduce efficiency as much as 30 percent. Snagging wheels require a comparatively coarse-grain corundum - about 12- to 24-mesh. Before the war, a considerable quantity of corundum was manufactured into so-called intermediate and fine wheels employed in finishing various machine parts, largely nonmilitary in character. The grain sizes in intermediate wheels ranged from about 36- to 60-mesh and in the fine wheels from 60-mesh up to around 150-mesh.

During the war period, however, the use of corundum has been restricted to its most essential applications in the conduct of war activities, that is, snagging wheels and optical uses. As indicated above, the coarse-grain products are made into snagging wheels. The finer-grain material (powder or flour) is consumed by grinders of optical precision instruments for military, naval, or indistrial use and for ophthalmic lenses. Applications include range finders, gunsights, searchlight mirrors, field glasses, periscopes, torpedo-tube sights, camera lenses, and other products requiring a high degree of precision and refinement. The superfines are used on grinding machines for rough grinding of lenses and then reclaimed and regraded into extremely fine sizes employed in finishing operations. These very fine grades are shipped practically all over the world in competition with Turkish and Naxos emery, particularly for use by opticians in the grinding and finishing of ophthalmic lenses.

The abrasive efficiency of a wheel or other cutting instrument depends upon a number of factors - the hardness of the abrading medium, the physical characteristics of the materials worked, the sharpness and angularity of the cutting edges, the type of fracture, the kind of binder, and the speed and pressure applied to the work. Corundum is admirably adapted for abrasive use, particularly because of its hardness, angular to conchoidal fracture, and sharp edges which break down readily, continually exposing fresh cutting surfaces.

Competition from artificial abrasives, such as silicon carbide (carborundum) and aluminum oxide, is severe. Except for certain rather specialized uses, the industry has tended to employ the artificial product because of its more uniform and readily controlled composition. For these specialized purposes, however, technical methods of operations and procedure have been developed to a remarkable degree. Complete change-over to the artificial abrasive has not been feasible. Such an eventuality would involve considerable change in shop routine, a long period for necessary technical investigation, and probably a high loss in unsatisfactory products. Unless it should become absolutely necessary through lack of or a shutting-off of the supply of suitable corundum, the over-all costs and operating troubles incident to such a change probably would not be justified.

PRICES

Corundum Ore

On February 9, 1942, the Office of Price Administration requested importers of corundum ore to report prices as of October 1, 1941, and to report pending changes in quotations with reasons therefor. The General Maximum Price Regulation, effective April 28, 1942, included corundum ore in its provisions and fixed price levels as of March 1942. Under amendment 17 to the General Maximum Price Regulation, dated July 25, 1942, a clarification of the meaning of the term "domestic ores and ore concentrates," as affecting all minerals (including, of course, corundum) was published. These definitions were as follows: "Ores" - any mineral substance in a crude state used chiefly as a commercial source of metal contained therein, and "ore concentrates" - any ore after removal of a part of the gangue or a part of the nonmetallic elements, either by a physical or chemical process.

Prevailing prices of corundum ore per long ton, packed in bags f.o.b. African shipping ports, in the latter part of 1941 were: Crystal ore, $69 per ton, and crushed boulder, $42. In January 1942, because of increased royalties paid in the Union of South Africa, these quotations were raised to $74 for crystal ore or concentrates and to $46 for crushed boulder. About this time, too, a new classification was added - massive crystal ore at $60 per ton. In the latter part of 1943, the price of both crystal and concentrates was raised to $83 per ton f.o.b. African ports. As determined by the Union of South Africa Government grading committee, the three grades of crystal most commonly exported are A_1, A_2, and B_3 (see p. 6). Concentrates are of three types, all sold at the same price as crystal: Boulder concentrate,

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largely a product of gravity concentration at the Pietersburg mill; plumasite concentrates, material broken or extracted from surface dykes; and crystal concentrates, mostly refuse, small crystals panned by individual operators or farmers.

Under Order 177 (sec. 1499.3 (b) of G.M.P.R.), effective December 10, 1942, the Metals Reserve Co. was permitted to sell and deliver South African crystal corundum ore to the American Abrasive Co., Westfield, Mass., at a maximum price of $88.10 per short ton, delivered at the purchaser's plant in Westfield. After representations that this figure did not cover actual costs of shipments from Africa, an amendment (No. 1) to Order 177 (sec. 1499.3 (b) of G.M.P.R.), effective February 6, 1943, permitted the Metals Reserve Co. to charge maximum prices of $107 per net ton for crystal corundum ore and $74 on sales of boulder corundum ore to the American Abrasive Co., delivered to the purchaser's plant at Westfield. As of February 22, 1943, corundum ore was covered into Maximum Price Regulation 327, which continued in effect the price levels of March 1942 and provided for filing price reports. Unless the material in question was sold to the Government, all import prices (including those for corundum ore) were frozen as of August 20, 1943, that is, could not be higher than the highest amount that the foreign seller charged the purchaser of the same class for the same materials during the 30 days preceding August 20, 1943.

Corundum Grain

Corundum grain was included under the General Maximum Price Regulation, effective April 28, 1942. According to an amendment to the corundum price control order (Order 3 under sec. 1499.75 (a) (4) of Supplementary Regulation 15 to G.M.P.R.) the American Abrasive Co., Westfield, Mass., was permitted on and after January 30, 1943, to sell, deliver, or offer for sale optical-grade grain corundum in all sizes, 60- to 250-mesh inclusive, at a price not exceeding 9.75 cents per pound f.o.b. mill. Grain corundum also was included under Maximum Price Regulation 327, which continued in effect the price levels of March 1942, unless subsequently specifically amended, and provided for filing price reports.

Quotations for grain corundum, as given in April and May 1944 by E&MJ Metal and Mineral Markets, are reported as follows (prices are in cents per pound for natural corundum for the sizes indicated): Sizes 8 to 60 inclusive, 8-3/4; 70 to 275, 9-3/4; 500, 30; 850, 45; 1,000, 45; 1,200 to 1,600, 65; and 2,600, 70.

MINING

Methods of recovering corundum in most regions of the world have been rather primitive. Often the material "mined" is merely "float" or boulder, gathered by native unskilled labor on an intermittent part-time basis or by local farmers when other duties were not pressing. This material is taken to small factors or receiving stations and graded roughly according to size and approximate purity. If exported, the corundum may then be shipped to tidewater, where often a second, more thorough grading takes place.

United States

In the early days of mining in Georgia and North Carolina, disintegrated or weathered ore was worked by pick and shovel and to some extent by streams of water which broke up the loosely consolidated rock. The corundum was then concentrated by hand washing. Later mining in Georgia, North Carolina, and Montana, was by shallow open pits in solid rock and still later, shafts and tunnels were developed. Slippage and caving in of rock caused much difficulty in underground mining, particularly in the peridotite region, due to the alteration of the peridotite to talc, serpentine, and other slippery rocks.

Canada

Corundum mining in Canada began about 1900 in Ontario. Operations at various times were undertaken at a number of locations in the southeastern part of the Province. Mining methods at the Craigmont deposits, where the bulk of Canadian corundum was obtained, may be considered typical of operations in this area. During the active life of the property, about 20 pits and open-cuts, some of which were 500 to 700 feet long and up to 250 feet wide, were excavated on the slopes of Robillard Mountain. The ore was blasted at the quarry face in large blocks, which were reduced by sledging or by dynamite (block-holing) to sizes suitable for crushing. After hand-sorting for waste and low-grade material, the crushed rock was hauled to a tramway and conveyed to the mill.

Union of South Africa

Large-scale mining in the Transvaal corundum fields has not been undertaken owing to a combination of local and rather special conditions. Deposits generally are quite small, unevenly distributed over a wide area, neither persistent nor regular in character, and not constant as to the amounts of corundum present. Only one type - crystal corundum - normally enjoys a reasonably steady, continuing market. Individual operations are small, varying from less than a ton to around 30 tons a month. The diggers, for the most part without capital, work only sporadically.

The ore is mined from open pits, generally not deeper than 20 feet. Picks and shovels, both for alluvial and reef deposits, commonly are the only equipment used, with some hand drilling and blasting in the harder rock. Hand-operated or power-driven cranes are employed in some of the deeper mines that reach 100 feet or more in depth, although in many operations the mined rock is shoveled from one platform to another until the surface is reached. Except where boulder corundum is recovered and marketed as such, efforts are made to recover as high a percentage of "crystal" corundum as possible.

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In alluvial workings a coarse screening, either by hand or mechanically, is followed by fine screening, the latter over one-eighth-inch mesh. The coarse screen product may be washed. Because of the high specific gravity of corundum, recovery by hand-sieving is fairly efficient. The finer sizes through one-eighth-inch openings are lost. Most of the corundum from the so-called "reef" or primary deposits has been obtained from rocks more or less weathered or softened, or from naturally friable rock. The larger crystals break away readily from the surrounding material, with little adhering gangue when this type of rock is mined. This is largely true also of the harder types of rock. Considerable hand-cobbing, however, becomes necessary. The preparation of the crystal corundum may stop at this stage, although the resultant marketable grade obtained may sometimes contain less than 50 percent of the total corundum content of the original ore. Further steps, however, may consist of rather primitive handcrushing or stamping with a steel rod and barrel cleaning or tumbling the crude hand-cobbed or sieved material. The latter method is the most generally used for cleaning corundum from reef deposits. If the rock to be treated is friable, as in corundum-bearing micaceous gneisses, a beater mill may be used. Cleaning not only is quicker with this type of equipment, but larger tonnages of ore can be run through. Boulder corundum, on the other hand, requires no treatment other than breaking up into pieces about 1 cubic foot or less in volume, or small enough to be conveniently handled. This may be accomplished by hand-sledging or by hand-drilling and blasting, followed by further reduction by sledging, if necessary.

MILLING

United States

The refining of corundum was quite simple during early development of the industry in the United States. After coarse crushing the raw material was screened and run through a series of troughs or sluice boxes in which the heavier corundum grains and corundum-bearing material sank to the bottom, and after removal from the troughs they were scrubbed in a scouring machine to free loosely adhering impurities. A concentrate was recovered from a second series of sluice boxes. This concentrate was ground with a muller or in chaser mills, put through a drier, and screened to commercially marketable sizes. The above method of refining was in general use in North Carolina and Georgia.' Later, however, more efficient milling was introduced both in North Carolina and Georgia, as well as in Montana, utilizing jigs for cleaning the larger sizes and Wilfley tables or Frue vanners for the finer fractions. Before refining mills were established in the southern Appalachian region, concentrates were shipped to Pennsylvania or even to Massachusetts for manufacture into the finer sizes required by consumers.

Canada

Plant operation in Canada, developed somewhat later, was more complicated than the comparatively simple milling practiced at producing mills in the United States. Canadian crude ore was crushed first to $2\frac{1}{2}$ inches and then to 3/8 inch and the coarser product run through coarse rolls. The finer material and the resultant from the coarse rolls was treated in trommels and by fine rolls and then run over two sets of finer trommel screens, yielding an elaborately sized product manufactured to close tolerances.

South Africa

Although extensive tests have been undertaken in the Union of South Africa with a view to the production of grain corundum and a salable concentrate by mechanical means, no permanent milling industry has resulted. During 1922 and 1923 corundum was concentrated at a mill near Bandolier Kop in northern Transvaal. Equipment consisted essentially of crushing or stamping and coarse screening apparatus, various jigs and classifiers, magnetic separators, and finally inclined vibrating screens. Milling and marketing difficulties led to abandonment of this operation in 1923. A new mill, also near Bandolier Kop, was erected in 1930, and crushing was done in three stages with jaw, disk, and roll crushers. Concentration also was somewhat more elaborate than for the earlier plant. Because consumers preferred to effect their own size classification, however, the final product was sold as an ungraded concentrate. Trouble was experienced in the uncertain quality of the raw material, which was obtained from many sources in the region near the mill. The varying character of the feed seriously affected the uniformity of the finished concentrate, hence the company ceased milling operations the following year. Within the last 2 or 3 years a mill said to contain modern concentrating and refining equipment has been built at Pietersburg. Details of its operations have not been released.

Other Countries

Information regarding concentration and milling practices in other countries is meager or not available. In Madagascar apparently corundum receives little preparation other than a rough sorting process. Although grades may be more standardized in India and some high-grade material is exported, shipments generally consist of crude concentrate or unsized crystal. Considerable exploitation of corundum is said to have taken place in U.S.S.R. in recent years. Published descriptions in English of Russian mining and concentration methods are not available to this office. Little is known of corundum operations and conditions of production in other regions. Output, however, generally has been small.

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